[0008] In an embodiment, the transformation may be a rigid-body transformation and the plurality of actions may comprise actions corresponding to predetermined adjustments of translation and rotation rigid-body transformation parameters. The plurality of actions may comprise respective actions corresponding to increasing and decreasing each of the translation and rotation rigid-body parameters by a constant or time-varying step size. The rigid-body transformation may be a 3D rigid-body transformation with rigid-body transformation parameters including three translation parameters and three rotation parameters. The rigid-body transformation may be a 2D rigid-body transformation with rigid-body transformation parameters including two translation parameters and one rotation parameter.

[0009] In an embodiment, wherein the plurality of medical images may include a first medical image and a second medical image and the transformation may be a dense deformation model that models deformations applied to the second medical image. The plurality of actions may comprise actions corresponding to adjustments to parameters of the deformation model. The first and second medical images may be registered by generating a dense deformation field corresponding to final parameters of the deformation model resulting from the plurality of iterations and warping the second medical image to register the second medical image with the first medical image by applying the dense deformation field corresponding to the final parameters of the deformation model.

[0010] In an embodiment, the intelligent artificial agent based image registration may be performed hierarchically using multi-scale image data. The determination of the current state observation, calculation of the action-values, and selection of the action having the highest action value may be repeated using a first image resolution of the plurality of medical images and a first machine learning based model trained using training images at the first image resolution until a first stop condition is reached. The determination of the current state observation, calculation of the action-values, and selection of the action having the highest action value may then be repeated using a second image resolution of the plurality of medical images and a second machine learning based model trained using training images at the second image resolution until a second stop condition is reached.

[0011] In another embodiment, a method for training an intelligent artificial agent to perform image registration according may include obtaining training image pairs and generating synthetic training image pairs, defining a state observation input for the artificial agent, defining a set of possible actions available to the artificial agent, defining a reward mechanism for learning a registration policy, and training a deep neural network (DNN) to predict action-values for the set of possible actions based on the state observation input using the training image pairs.

[0012] These and other advantages of the invention will be apparent to those of ordinary skill in the art by reference to the following detailed description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIGS. **1**A and **1**B illustrate examples of medical image registration problems that present challenges to traditional optimization based image registration techniques;

[0014] FIG. **2** illustrates a method for training an intelligent artificial agent to perform image registration according to an embodiment of the present invention;

[0015] FIG. **3** illustrates a method for image registration using an intelligent artificial agent according to an embodiment of the present invention;

[0016] FIG. **4** illustrates a framework for artificial agent image registration using the method of FIG. **3** according to an embodiment of the present invention;

[0017] FIG. **5** illustrates a method for rigid registration of medical images using an intelligent artificial agent according to an embodiment of the present invention;

[0018] FIG. **6** illustrates and exemplary deep neural network (DNN) for rigid 3D/3D medical image registration according to an embodiment of the present invention;

[0019] FIG. **7** illustrates a method of hierarchical image registration using multi-scale image data according to an embodiment of the present invention;

[0020] FIG. **8** illustrates exemplary registration results for spine computed tomography (CT) and cone beam CT (CBCT) registration and cardiac CT and CBCT registration;

[0021] FIG. **9** illustrates a comparison of supervised deep reinforcement learning and unsupervised deep reinforcement learning for 2D/2D spine image registration;

[0022] FIG. **10** illustrates a method for deformable registration of medical images using an intelligent artificial agent according to an embodiment of the present invention;

[0023] FIG. **11** an exemplary idealized deformation trajectory between a moving image and a fixed image;

[0024] FIG. **12** illustrates an exemplary DNN for deformable image registration according to an embodiment of the present invention;

[0025] FIG. **13** illustrates a Gaussian radial basis function (RBF);

[0026] FIG. **14** illustrates a framework for decoding encoded flow actions output from a trained DNN according to an embodiment of the present invention;

[0027] FIG. **15** illustrates examples of deforming a contour of an organ of interest using Gaussian kernels;

[0028] FIG. **16** illustrates patch extraction from landmark positions of a moving image;

[0029] FIG. **17** illustrates a framework for performing a second stage of a multi-stage deformable registration according to an embodiment of the present invention;

[0030] FIG. **18** illustrates a method of autonomous intelligent artificial agent based cognitive image fusion according to an embodiment of the present invention;

[0031] FIG. **19** illustrates a method of training a DNN for deformable image registration using weakly supervised deep dense correspondence learning according to an embodiment of the present invention;

[0032] FIG. **20** illustrates an exemplary network architecture for a Convolutional Encoder-Decoder Network for dense correspondence estimation;

[0033] FIG. **21** illustrates an exemplary Flow-Net like deep architecture for dense correspondence estimation;

[0034] FIG. **22** illustrates a method for deformable registration of medical images according to an embodiment of the present invention; and

[0035] FIG. **23** is a high-level block diagram of a computer capable of implementing the present invention.